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KNOWLEDGE TRANSFER FOR FRUGAL INNOVATION: WHERE DO ENTREPRENEURIAL UNIVERSITIES STAND?

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ABSTRACT

Purpose: Frugal innovation has gained prominence based on its potential contribution to sustainable development and the new opportunities that it offers to low-income customers. This paper analyses the strategic knowledge transfer practices implemented by an entrepreneurial university for fostering frugal innovations within an emerging economy.

Methodology: We adopted a case study methodological approach. The selected case was the University of Campinas (Unicamp), one of the leading universities in Brazil in terms of research quality and technology transfer. The study built upon 14 interviews with key informants and secondary sources of data (official and public documents).

Findings: Our findings highlight the multidimensional dynamics of frugal innovations arising from university-industry relationships. Key dimensions considered include the internal capabilities of universities to foster frugal innovations and connect them to markets, the surrounding innovation ecosystems in which the university is embedded, and the overarching institutional framework.

Research limitations: The analysis of strategic management practices for frugal innovation requires an evolutionary perspective, but we lacked sufficient longitudinal information for a formal evaluation. Also, since our empirical analysis is based on an in-depth case study of one university, further validation in other contexts would be necessary.

Practical implications: The study offers new insights regarding the effectiveness of university-business collaboration partnerships for developing frugal innovations in emerging economies. Policymakers should promote societal programs enhancing the active participation of all agents involved in the entrepreneurial and innovation ecosystem. University managers should understand the challenges and the opportunities behind the adoption of an inclusive and societal orientation.

Social implications: By adopting frugal innovation practices, universities can enhance their contribution to meeting the United Nations' Sustainable Development Goals.

Originality: The literature on frugal innovation has emphasized the importance of networking between different types of firms, NGOs, and governments, but the role of universities in frugal innovation remains mostly unexplored. Our study addresses this gap by exploring how entrepreneurial universities participate in frugal innovations to meet societal challenges.

Keywords:
Strategic Knowledge Transfer Management; Frugal Innovation; Sustainable Development; Entrepreneurial University; Entrepreneurial and Innovation Ecosystems; Social Innovation Approach; Emerging economies; Brazil

1. INTRODUCTION

The academic discussion around frugal innovation has been gaining relevance in both emerging and advanced economies (Agarwal and Brem, 2017; Agarwal *et al*., 2017; Crisp, 2014; Lim and Fujimoto, 2019; Melkas *et al*., 2019; Pisoni *et al*., 2018). Frugal innovation is understood as the process of reducing complexity and costs during the design and development of smart solutions (product/services) to meet the needs of low-income customers (Zeschky *et al*., 2011) and generate institutional change in their societies (Karnani, 2007). Frugal innovations have been supported by an inclusive approach of contributing with social innovations to the development of new products/services that meet societal needs (Chataway *et al*., 2014; Lorentzen, 2010; Murray *et al*., 2010).

Although the involvement of multiple agents is widely recognized as a key factor for the success of frugal innovations (Altmann and Engberg, 2016; Annala *et al*., 2018; Leliveld and Knorringa, 2018; Martínez *et al*., 2018; Tiwari and Herstatt, 2012), the contribution of universities on frugal innovation is underrepresented in the existing literature (Bayuo *et al*., 2020; McKelvey and Zaring, 2018). Over the last two decades, the literature has legitimised the significant contributions of entrepreneurial universities through the generation of human capital, graduate/academic entrepreneurs, as well as the dissemination/commercialisation of knowledge that contributes to strengthening societal, economic and technological development (Audretsch, 2014; Guerrero and Urbano, 2012; Guerrero *et al*., 2015; Guerrero *et al.*, 2016a; Klofsten *et al.*, 2019). Notwithstanding, we still lack a clear understanding of how entrepreneurial universities are managing their knowledge capabilities to effectively promote societal impacts in emerging economies (Guerrero *et al.*, 2019a, 2019b). Whereas frugal innovation does not always need the development by higher education institutions of novel technologies, entrepreneurial universities may foster frugal innovations by providing the required skills, supporting entrepreneurial and innovation initiatives, and conducting applied research to meet societal needs (Arocena and Sutz, 2017; Brundenius *et al*., 2017; Guerrero and Urbano, 2019).

Against this background, the objective of this paper is to analyse the strategic knowledge transfer practices implemented by entrepreneurial universities for fostering frugal innovations in the context of emerging countries. Specifically, our empirical assessment deals with the case of the University of Campinas, Brazil. It constitutes an interesting empirical scenario for at least two reasons. First, within the context of the so-called "social outreach movement," since the 1990s Brazil has implemented new policies to integrate extension activities into the teaching curricula and research activities of universities, in order to instigate a transformative relationship between universities and society (Renault *et al*., 2017). Second, the University of Campinas is one of the leading Brazilian universities in terms of research and technology transfer outputs. Over the years, it has become increasingly engaged in addressing the societal challenges of the region where it is located.

The remainder of the paper is organised as follows. Section 2 develops the conceptual framework, focussing on the intersection between entrepreneurial universities, knowledge transfer practices, and frugal innovation. Section 3 describes the methodology, and Section 4 summarizes the results. Section 5 discusses the main findings, offering set propositions concerning the relationships between entrepreneurial universities and the dynamics of frugal innovations. Finally, Section 6 concludes by outlining practical implications and avenues for future research.

2. ENTREPRENEURIAL UNIVERSITIES IN THE CONTEXT OF FRUGAL INNOVATION

Although the definition of the frugal innovation phenomenon is in flux, most of the literature refers to events associated with products and services being offered at affordable prices in socio-economic environments characterized by resource scarcity (Hossain *et al*., 2016; Leliveld and Knorringa, 2018). In addition to addressing the needs of the weak, frugal innovation is often based on economizing the use of scarce natural resources and recycling them whenever possible, leading to more environmentally-sustainable solutions (Basu *et al*., 2013). In sum, frugal approaches to innovation are oriented towards

overcoming challenges associated with resource constraints and adversities related to poverty, institutional voids, and environmental threats (Pisoni *et al*., 2018).

The difficulty in reaching a conceptual consensus over the term relates to the fact that "*FIs* [Frugal Innovations] *emerge from a variety of sources with varying degrees of sophistication, so framing various types of FI into a standard structure is challenging*" (Hossain, 2018, p. 933). In this sense, by addressing societal challenges, frugal innovation may be included within the scope of the broader notion of 'social innovation' (Steinfield and Holt, 2019; van der Have and Rubalcaba, 2016). While each concept involves different analytical foci, they both contemplate the promotion of social well-being and population empowerment as processual outcomes (Kahle *et al*., 2013). These effects are achieved through impacts involving the development of inclusive markets, serving vulnerable populations, empowering the workforce and local entrepreneurs, developing new supply chains, efficient use of resources, and reduction of social inequalities (Hossain, 2018; Kahle *et al*., 2013).

While substantial research has addressed the dynamics of frugal innovation from the perspective of individuals and firms, scant attention has been paid to universities as intervenient agents in these processes (Bayuo *et al*., 2020). Notwithstanding, income and knowledge inequalities have generated expectations that universities integrate social aspects as a core part of their activities (Bayuo *et al*., 2020). The closer alignment of universities and underserved communities aimed at transferring knowledge for inclusive development becomes a critical feature for the generation and diffusion of frugal innovations that can reach out beyond local markets (McKelvey and Zaring, 2018). In turn, more efficient interactions between academia and its ecosystem can leverage impacts related to the satisfaction of human needs (Cajaiba-Santana, 2014; Rao-Nicholson *et al*., 2017; Turker and Vural, 2017; van der Have and Rubalcaba, 2016).

In this vein, universities' knowledge transfer processes can play a pivotal role in driving inclusive development if they incorporate agendas associated with pressing societal challenges (Arocena *et al*., 2015; Melkas *et al*., 2019; Pisoni *et al*., 2018; Steinfield and Holt, 2019). In this regard, a particular dimension – often overlooked in the frugal innovation literature – is associated with the scientific competences of universities, which can enable more efficient use of resources and enhanced functionality for vulnerable communities (Dost *et al*., 2019; Rao, 2019). Accordingly, the provision of academic research dedicated to tackling social needs at the local level functions as a key enabler of frugal innovation (Niroumand *et al*., 2020). In order to effectively turn these ideas into practice, universities must be integrated as parts of complex ecosystems that can combine knowledge to promote frugal innovation (Hart *et al.*, 2016; Melkas *et al.*, 2019; Sharmelly and Ray, 2018). Ultimately, this represents a shift from the traditional perspective of firms and individuals "creating frugal innovations" to a "harvesting" paradigm structured around open innovation strategies (Ardito *et al.*, 2018; Hartley, 2014). We now explore further how these changes can take place based on entrepreneurial universities' capabilities.

2.1 Linking entrepreneurial universities' capabilities and frugal innovation

Beyond the traditional university missions (teaching and research), entrepreneurial universities are enhancing the so-called "third mission" linked with their contributions to societal and economic development (Guerrero *et al*., 2015, 2016; Klofsten *et al*., 2019; OECD, 2017). The entrepreneurial university literature has associated the third mission with knowledge transfer/commercialisation (i.e., patents, licenses, intellectual property rights), and entrepreneurial innovation initiatives (i.e., start-ups, spin-offs) (Audretsch, 2014; Guerrero and Urbano, 2019). It has underscored the relevant contribution of universities in the configuration of regional entrepreneurial and innovation ecosystems (Herrera *et al*., 2018). Beyond targeting purely economic outcomes, in recent years entrepreneurial universities have been reorienting their capabilities towards sustainable societal development, influenced by the United Nations' Sustainable Development Goals (Durán-Romero and Laguna-Molina, 2017; Guerrero and Urbano, 2016b, 2019; Klofsten *et al*., 2019; Lozano *et al*., 2015; Renault *et al*., 2017).

Stimulating frugal innovations requires building up strategic capabilities throughout the various university dimensions (individual, research group, faculty, or university), in order to ultimately institutionalise social and frugal innovation logics within the mission of universities (Benneworth and Cunha, 2015; Rasmussen and Borch, 2010).

First, to achieve successful societal engagement, entrepreneurial universities must adopt leadership and governance systems that promote an organizational culture oriented towards frugal innovation (Heaton *et al*., 2019; Leih and Teece, 2016). It implies including social partners, by giving them a voice on the university board/committees, or at least to introduce the stakeholders' vision as part of the university strategies (Benneworth and Jongbloed, 2010; Natalicchio *et al*., 2018). Recent research suggests that a more robust engagement of stakeholders from civil society democratizes the decision-making process; results in closer alignment between scientific priorities and social needs; accelerates the diffusion of research outputs; and enhances trust and transparency (Cope *et al*., 2018; Olsen *et al.*, 2016; Willyard *et al.*, 2018).

Second, entrepreneurial universities must develop capabilities to collaborate with multiple stakeholders (Arocena and Sutz, 2017). To promote frugal innovation, entrepreneurial universities need to enhance their cooperation with multiple local/foreign businesses (start-ups, SMEs, and established firms), as well as other socio-economic agents. In this vein, entrepreneurial universities can, for instance, stimulate "grassroots" innovation developed by communities and civil society (Chaminade *et al*., 2018; Cozzens and Kaplinsky, 2010) or establish linkages that promote the diffusion of frugal technologies to target individuals and markets (Rao, 2019). Following this latter example, TTOs can identify existing research projects with possible implications for frugal innovation and ensure proper disclosure of their results, searching for business opportunities in cooperation with private partners. Moreover, intermediary organisations can be transformed to explicitly include within their missions the need to link with poor communities[1] (Kruss, 2017).

2.3 Entrepreneurial universities' role in developing students' skills for frugal innovation

The student body is another critical element for entrepreneurial universities to establish ties with communities and foster frugal innovations (Melkas *et al.*, 2019). Accordingly, in parallel to the generation and transfer of appropriate knowledge, a key objective of entrepreneurial universities with social engagement is to ensure that their students acquire the necessary skills to address social demands.

A key practice for entrepreneurial universities to foster such engagement is through continuing education programs on topics related to frugal innovation, social inclusion, and environmental challenges (Arocena and Sutz, 2017). For this purpose, collaboration with external stakeholders in curriculum design and delivery is critical for entrepreneurial universities to be able to provide relevant skills on frugal innovation to students (Guerrero and Urbano, 2019). In order to build the required skills for frugal innovation, entrepreneurial universities should emphasise problem-based learning as well as entrepreneurship education programs across a wide range of scientific and social disciplines (Guerrero *et al*., 2018). More concretely, in Science, Technology, Engineering and Mathematics (STEM) fields, the transfer of frameworks, techniques, and tools (e.g., design for cost, design for manufacturing, value-sensitive design, or design for sustainability) can facilitate the emergence of frugal innovations (Blume-Kohout, 2014; Guerrero and Urbano, 2016a).

[1] An interesting example is the Technological Incubator of Popular Cooperatives (ITCP) of the Federal University of Rio de Janeiro, Brazil. It was established in 1995 as an extension program focusing on developing new cooperatives among socially deprived groups (such as unemployed or underemployed workers; users of the mental health system; and recyclable waste pickers groups). This model later became an official program of Brazil's federal government, was replicated in more than 60 locations, and was elected as one of the country's ten most important programs to fight poverty (Renault *et al.*, 2017).

3. METHODOLOGY

3.1 Case study approach

Despite the problems of sampling bias, subjectivity, and lack of generalizability, the case study method is useful for exploratory analyses of emerging research topics and theory development (Eisenhardt, 1989). The selected case study deals with the University of Campinas, one of the leading universities in Brazil, in most indicators related to research quality and technology transfer intensity. This case was selected adopting the theoretical criteria to identify entrepreneurial universities adopted in extant studies (Guerrero and Urbano 2012, 2019; Guerrero *et al*., 2015): (i) the promotion of an entrepreneurial culture across the university community; (ii) making self-instituting efforts to develop an entrepreneurial ecosystem and fostering innovative/entrepreneurial initiatives; (iii) socio-economic impact on the regions/countries; (iv) continued and sustained transformation process, and (v) involvement of several socio-economic actors in the decisions, activities, and objectives.

The research strategy begins with an in-depth evaluation of public documents from the University of Campinas that allowed identifying agents of interest, as well as understanding the organisational profile of the university and in particular, its orientation towards: (i) engaging in regional development processes and fostering inclusiveness; and (ii) building linkages with firms in specific projects related to frugal innovation. Subsequently, personal interviews were conducted by our research team with four categories of agents within the organisation, namely: Institutional Representatives, Student Organizations, Research Centers & Groups, and Academic Spin-offs. An additional interview was held with a large multinational company that has a history of interactions with the University of Campinas, which offered a complementary perspective from an external stakeholder.

We used snowball sampling to reach individuals of interest in our assessment, starting from the university's technology transfer officers. A total of 14 interviews were undertaken in March, April, and May 2019 (Appendix 1). All interviews were recorded with the consent of participants, fully transcribed by two research assistants, and analysed by the authors. The profiles of interviewees are not presented in further detail to respect individuals' privacy[2]. Although with variations and adaptations, according to interviewees' categories, the interview scripts addressed:

a. Level of institutionalisation of frugal innovation in science and technology transfer activities;
b. Dynamics of university-business collaborations and potential linkages with frugal innovations;
c. Strategic technology transfer practices and their potential for promoting frugal innovations;
d. Future challenges concerning further contributions of university-business connections to the broader socio-economic environment.

A key challenge in this empirical assessment concerns the use and precise comprehension of the term frugal innovation for the Brazilian academic context. First, this concept is not widespread in Brazil, so most interviewees were not familiarised with it. In order to tackle this issue, we prepared a brief introduction based on relevant literature, to offer a comprehensive perspective on our research goals. While effective, this approach still caused some confusion, as many interviewees were researchers more closely connected to scientific advancements than to innovation *per se*. In these cases, we adopted a more open strategy for conducting interviews, extracting aspects that could be associated with the notions of frugal and social innovations during the analyses of transcripts.

The information gathered through the interviews was coded and analysed concerning the key analytical categories emanating from our review of the existing literature, as summarized in Section 2. The analysis of the encoded and triangulated data involved the search for common patterns among interviews (Yin, 2003), thereby strengthening the internal validity of the research (Appendix 1). Following Eisenhardt (1989), the data was interpreted against the light of the existing literature, and our analysis was guided

[2] This procedure follows recommendations from the Research Ethics Committee from the University of Campinas. Interviews were approved under the protocol #89010418.2.0000.8142/Project 'Universities as Pivotal Agents in Innovation Ecosystems'.

by attempts to achieve "literal replication" (predict similar findings) and "theoretical replication" (predict contrasting results but for predictable reasons).

3.2 Research setting

Brazil is an interesting empirical setting to explore the contribution of universities into frugal innovation. During the last two decades, the Brazilian government has placed a stronger focus on promoting a more inclusive and socially-oriented higher education and innovation system (Renault *et al*., 2017). The University of Campinas (Unicamp) is one of the leading public universities in both Brazil and Latin America. The university spreads across six campuses, 24 institutes, 21 research centers, and three hospitals. It hosts around 2,000 lecturers/professors with a Ph.D. degree (99%) and 20,000 students. Over 10% of all Brazilian indexed scientific articles have at least one co-author from Unicamp (Guerrero *et al*., 2014). Unicamp is also acknowledged as one of the most prolific Latin American institutions in terms of technology transfer (Dias and Porto, 2018).

In turn, the Campinas region is one of the most prolific entrepreneurial and innovation ecosystems in Latin America (Fischer *et al*., 2018). However, like any emerging economy, the region faces institutional voids that generate strong socio-economic inequalities. Given these trade-off conditions, inclusion is one of the main challenges of Campinas. Inspired by the need to address this challenge, in 2015, Unicamp adopted a dual strategy to contribute to regional development: (a) social engagement orientation to support social and frugal innovations, and (b) entrepreneurial orientation to support the commercialisation of technological innovations. Based on this strategy, Unicamp foresees a deeper integration between its academic role and social demands from society, fulfilling its developmental goals that date back to its foundation.

4. FINDINGS

4.1 The evolution of Unicamp's technology transfer practices

The evolution of Unicamp's technology transfer practices can be characterized in three stages. In the first stage, during the 1980s, Unicamp became a pioneer in the Brazilian context in developing and protecting its intellectual property (IP) portfolio. Concretely, the university established formal mechanisms to protect its IP and license it out to industrial partners. In this initial stage (Interview 1), the main challenges involved establishing long-term connections with industrial partners and achieving higher levels of trust and operational alignment with companies, taking into account the existence of cultural conflicts between academia and industry.

In the second stage, Unicamp's first Technology Transfer Office (TTO) was created in 1990 to institutionalise technology transfer processes further, to provide new incentives and support services to university researchers, and to reduce the mistrust between the university and firms (Hertzfeld *et al*., 2006). As a result, Unicamp became the most active patent assignee in Brazil, as well as the most active university in terms of cooperation with industry in the country (Fischer *et al*., 2019). However, the existing structures and knowledge strategies started to become obsolete by the end of the 1990s. Consequently, in 2003, the TTO was absorbed by the Innovation Agency[3] (INOVA), which adopted a more proactive, broader, and longer-term approach to intensify Unicamp's engagement with industry. INOVA also manages the technology transfer activities of the Unicamp's R&D partnerships, Science Park, Business Incubators, and Entrepreneurship Centre.

In the third stage, as the university adopted a more durable pro-social profile, it became clear that existing technology transfer practices needed to change in order to support that transition. The university's IP portfolio was not well aligned with societal needs. Beyond patenting and licensing, new initiatives and metrics became necessary to adequately capture the contribution of the university to social

[3] Currently, the staff of INOVA consists of about 35 full-time employees.

and frugal innovations. Its specialisation drives the university's potential contribution to frugal innovation in some key areas such as health sciences, electrical engineering, computing, mechanical engineering, biology, chemistry, energy, and petroleum. Unicamp's R&D partnership capabilities with public and private agents involved in the regional innovation ecosystem represent another opportunity for a strong social and frugal innovation contribution. This third stage started around 2005 with the implementation of the Brazilian Innovation Act instated in 2004. This new regulatory framework sought to promote closer relationships between universities and markets to trigger regional development. This stage is still ongoing, as we shall discuss in the following section.

4.2 Unicamp's technology transfer practices and challenges for frugal innovation

Through the interviews, we identified the following four representative cases of technology transfer practices fostering frugal innovation.

- The Center for Petroleum Studies was created within the university in 1987, building on partnerships with Royal Dutch Shell, Petrobras, and the Brazilian State Oil Industry. The purpose of this centre was to address technological barriers in the oil and gas industry. According to our interviews, all of this joint research ultimately translates into a better quality of training for students (a practice of skills transfer via teaching activities), as well as the contribution to societal goals and climate impacts (a practice of technology transfer for frugal innovations via research activities).
- An R&D project to use natural resources (polyurethane from Açaí and derivation of biomaterials from sugarcane molasses) for applications in plastic surgery was initiated in 2009. This project has the potential of exponentially aggregating value to this crop, generating wealth for those communities involved in harvesting it.
- Unicamp's partnership with the São Paulo Power and Energy Company (CPFL, part of the Chinese Group State Grid) was initiated in 2017, to generate efficient and sustainable energy. Field tests were carried out at Unicamp's main campus under the *Sustainable Campus* project. In this case, the geographical proximity allows for an intensive flow of Unicamp' students to the partner's premises.
- Drawing from the Sustainable Campus experience, Unicamp has widened collaborations, incorporating other universities, companies, and governmental bodies to jointly create the International Hub of Sustainable Development in Campinas. According to the interviewed Institutional Representative, this Hub aims at "*fostering research, teaching and outreach activities from Unicamp that focus on sustainable socio-economic development*."

Although these kinds of frugal innovation initiatives are generating an intense technological activity with a social orientation, two main challenges were highlighted during interviews. On the one hand, the difficulty of concatenating university interests with the autonomy of researchers. It can become critical when state-of-the-art technologies do not necessarily translate into cost reduction in products and processes in the short term. In this vein, one of the interviewed researchers stated that "*if some of the technologies can be cheaper than available standards (frugal), they are not necessarily affordable for disadvantaged populations. It should also be pointed out that they represent potential opportunities for technology upgrading, as they substitute imported goods that are not currently produced in Brazil".*

On the other hand, the lack of rewards/incentives for undertaking frugal innovation initiatives was identified as critical challenge by researchers and entrepreneurs from spin-off companies. It also relates to the limited market demand for science-based products in the country and the consequent scant access to specific lines of funding (for researchers) and venture capital (for entrepreneurs). Given the nature of applicable knowledge produced by the university, its evolution towards standardised products that can reach enough scale to become accessible for a broader market seems to hamper a further integration of academia into the dynamics of frugal innovation.

Regarding the influence of regional capabilities for frugal innovations, the interviews revealed that the existence of an institutional framework had facilitated networking for frugal innovation among the constituents of the regional innovation ecosystem. On the one hand, Institutional Representatives highlighted that social and environmentally responsible policy had affected industrial demands during interactions with Unicamp. This perception is also supported by researchers involved in an R&D project

addressing issues related to environmental sustainability and energy efficiency. The interviewees recognized the impact of sectoral policies on the promotion of joint R&D projects with public/private agents, as well as strategic mechanisms that have strengthened connections with industry. Similarly, interviews with research center members and entrepreneurs belonging to spin-off companies have stressed the importance of Unicamp's technology transfer structures. According to their perceptions, the Innovation Agency facilitates the approximation with industry as well as actively fosters a stronger (social) entrepreneurial culture among the academic community, thus promoting frugal innovations.

As expressed by a research group leader, "*in the past, collaborating with companies was frowned upon in the public university, you could only do research. Then one day, we ran out of money, and people started asking, 'how are we going to fund research now? Now we have to resort to private firms' […] younger researchers and faculty are also renewing the environment with fresher ideas*". On the other hand, these processes do not take place quickly. One researcher from a different research group had the perception that, except for multinational firms, there is a lack of engagement in R&D collaboration for frugal innovations in Brazil. In this vein, a manager from a large firm described the evolution of relationships with the university as moving from initial informal contacts that usually take years to translate into actual joint projects. In this regard, what the firm notices is "*complementarity […] Unicamp offers strong conceptual and academic knowledge […] when you bring in an academic partner, with a different perspective […] it is there where new technology comes to life, a new concept, that is going to be applied further down the road"*.

Similarly, the perception from companies also points to barriers associated with the slowness of internal processes at the university, turning contractual agreements into excessively lengthy processes. Additionally, another critical form of integration consists in the extensive flow of undergraduate and graduate students to occupy positions at firms, an aspect that is perceived as a relevant source of input for further interactions with the academic environment, reinforcing the idea that this shared research environment can improve the quality of teaching. The typical characteristics of frugal innovation projects are likely to compound all those challenges, particularly when articulated in partnership with small and informal businesses from poor communities.

4.3 Unicamp's skills transfer practices and the role of students

Unicamp has established entrepreneurial and social innovation as two critical areas in its educational portfolio. Besides offering traditional entrepreneurship courses for students from different disciplines, strong institutional support exists for junior enterprises, involving undergraduate students in business activities from an early stage of their formation.

Also, Unicamp has a strong commitment to the inclusion of low-income students. A cornerstone initiative in this regard is the Program for Higher Interdisciplinary Education (ProFIS). This pioneering program in Brazil favours students from public high schools in Campinas facing situations of social vulnerability. It allows them to undertake an interdisciplinary education program for two years before deciding if they wish to pursue a formal university degree. Moreover, Unicamp has long been including social and racial quotas in its entry exams, aiming at reducing access inequalities. Its latest action in this regard was the engagement with indigenous communities to select students from tribes in the Amazon region. Most importantly, these programs are complemented with strategies to reduce dropout rates, with the provision of financial assistance through scholarships, psychological services, and access to housing facilities.

Other forms of student engagement with frugal, social, and environmental innovations involve active learning in research projects. For instance, a new course for undergraduates has its focus on the development of a pipeline for household energy generators, starting from technical feasibility studies and reaching the stage of prototypes by the end of the program. An interview with a Research Group leader clarified that when this kind of initiative is embedded in joint projects with industry, there are often offerings of scholarships funded by companies. In this sense, Unicamp is incorporating students as an integral part of its developmental activities and frugal innovation projects.

Student bodies represent a relevant part of the educational development, going beyond the classroom and laboratories, promoting social entrepreneurship and linkages with vulnerable communities. However, interviewed students highlighted two challenges. First, given the low level of engagement of faculty members in students' initiatives, the challenge is improving inclusion through Unicamp's research and mentoring projects, which tend to focus on more technologically advanced projects led by senior faculty. Second, although structures and innovation models exist, their translation into application implies the need for cost-effective technology. A relevant example of such type of frugal innovations is a recent project to develop tents designed to assist populations from areas affected by natural disasters, resulting in products that are affordable and simple to assemble. Given the resource scarcity, the main challenge here was the limited availability of funds for undertaking frugal-oriented projects.

4.4 Beyond science: Unicamp as a cradle for entrepreneurs

During our interviews, academic entrepreneurs have clearly expressed that the culture of the university promotes entrepreneurship through dedicated policies and initiatives. In this regard, the strategic importance of business incubators was highlighted, offering managerial support and access to networks that enhance the capabilities of these new ventures. Unicamp offers not only an incubator for high-tech ventures, but also an incubator dedicated to supporting social technologies, oriented towards promoting inclusion, and generation of income for vulnerable groups. Projects include cooperatives that deal with basic sanitation and agroecological techniques. Interestingly, this environment is strongly connected with research activities, and several undergraduate and graduate students have been involved in training and research focusing on the dynamics and impacts of these businesses. Also, the Unicamp Ventures Community was launched in 2006 as a structure that seeks to thicken entrepreneurs' connections with other agents – such as the financial system – and to offer mentoring for newcomers.

The exchanges that take place through academic collaboration with the outside environment – including firms and research institutes - have been pinpointed by interviewed academic entrepreneurs as a critical pillar for achieving technological development, indicating the role of a dense ecosystem. In practical terms, these linkages were translated, for example, into technologies that allow early detection of breast cancer that can be applied at significantly lower costs than existing apparatuses used for mammography. Other spin-offs achieved similar cost reduction results for the physical rehabilitation of medical patients and bioengineering techniques. These serve to illustrate the results achieved in terms of health-related frugal innovations, a significant area of interest in this domain (Bianchi *et al*., 2017).

Close ties with companies in a large research project for environmental sustainability and efficiency also resulted in many spin-off companies, as reported by a Research Group leader. In this regard, the project functioned as a testing field for developing new technologies, while networking activities with large incumbent firms opened up market opportunities for students to pursue entrepreneurial career paths. Again, the entrepreneurship-friendly culture of the university facilitated these processes. Besides, the financial support provided for R&D in small companies has proved strategic to leverage these start-ups. Behind these funding is the São Paulo Research Foundation (Fapesp), a state-level public entity,

Despite those success stories, the promotion of entrepreneurship within Unicamp faces substantial challenges, which are even more significant in the case of social and frugal innovations. It can be attributed to the overall regulatory framework and macroeconomic conditions of the Brazilian economy, as well as a lack of training for entrepreneurship in STEM fields. A Research Center leader emphasised these barriers: "*where are the spin-offs? It is all challenging in Brazil […]We are not trained to become entrepreneurs. It is only now that this model has become known […] in doctoral theses I start to perceive a context of market orientation and innovation, aiming at generating products or processes, and that the student is no longer dependent on finding a position as a faculty member in a university, he now can become an entrepreneur*". An additional aspect of interest in this discussion refers to the bureaucratic requirements for entrepreneurs to remain connected to the university's laboratories and research infrastructure. One entrepreneur highlighted that the documentation and procedures he has to go through in order to formalise a partnership with a research unit of Unicamp are excessive for a small firm. While

large corporations can dedicate resources and people to navigate through these processes, it becomes hard for a start-up to dedicate time to this. As a result, there is a lack of incentives for spin-offs to collaborate more closely with academia once their company is created.

5. DISCUSSION

The case study analysis enables us to suggest a set of theoretical propositions, which nevertheless should be taken as tentative, given the partial and exploratory nature of our empirical study. We expect that these propositions can offer insights to develop a research agenda on the contribution of entrepreneurial universities to frugal innovation. Figure 1 presents a conceptual framework to understand the elements that should be considered in the design of entrepreneurial universities' strategies to manage technology and skills transferred during the development of frugal innovation projects. We advance on the model proposed by McKelvey and Zaring (2018) by offering a more detailed perspective of agents and flows involved in the generation and diffusion of frugal innovations originating from academic settings. Following our case study, we also add emphasis to the contextual conditions involved in these dynamics, including the innovation ecosystem, dedicated policies, and the connection between frugal innovation and broader societal outcomes.

---- Insert Figure 1 here ----

The entrepreneurial university's capabilities are relevant conditions in the implementation of strategic practices for managing the transfer of technology and skills from academia for the generation of frugal innovations. Our findings point to various challenges at the university level associated with translating scientific and technological developments into accessible, inclusive, and sustainable innovations. In particular, critical elements identified in our field research encompass the internal dynamics of relationships among members of the academic community, bureaucratic procedures regulating interactions with external agents, and incentive systems associated with performance measurement and rewards. These findings are aligned with prior observations on processual conditions for social and frugal innovations to arise (Bayuo *et al*., 2020). Assuming the relevance of university capabilities, our case study results lead to the following proposition:

> Proposition 1: The effectiveness of entrepreneurial universities' strategies for managing technology transfer in frugal innovations is shaped by the university capabilities associated with:
> a. *Leveraging a collaborative culture involving all members of the academic community and oriented towards the generation of positive social impacts.*
> b. *Setting up institutional channels that facilitate connections with external agents to facilitate co-creation of value for underserved groups of society.*
> c. *Designing incentive structures that reward the commitment of researchers and faculty with frugal innovation projects based on high-quality science.*

Regarding the industry side, the results of our analysis suggest that firms can also benefit from establishing linkages with universities based on frugal innovation dynamics. While universities in Brazil are often perceived as potential sources of advanced R&D (Fischer *et al*., 2019), contributions could be enhanced by a stronger focus on cost-effective, sustainable products and processes. As our interviews demonstrate, academic spin-offs often face barriers associated with the difficulty of achieving scale – a hurdle that could be overcome through closer cooperation with incumbents. By reaching out to large, untapped markets, firms could achieve higher levels of competitiveness through joint initiatives with universities, ultimately generating higher levels of social welfare.

Following this rationale, regional capabilities embedded in the innovation ecosystem seem to be critical for institutionalising and legitimising the social orientation of knowledge transfer from academia. The capabilities required for universities and firms justify why policymakers should play a role in facilitating

the establishment of linkages in innovation ecosystems. In this process, technology upgrading should be coupled with more immediate needs associated with vulnerable communities and the natural environment. Also, our case study highlighted the critical role of the São Paulo Research Foundation (Fapesp) in promoting university-business interactions through the funding of research projects and also through initiatives that explicitly target technology transfer. Assuming the relevance of industrial capabilities and social engagement, we propose:

> Proposition 2: The effectiveness of entrepreneurial universities' practices towards the generation of frugal innovations is ***moderated by the dynamics of surrounding innovation ecosystems***, comprising complementary agents, institutions, the density of interactions, and overall orientation towards societal and environmental impacts.

Lastly, in a broader context, industrial policies and science, innovation, and higher education policies delineate the rules of the game concerning agents' behaviour towards frugal innovation practices. As shown in Figure 1, the density of connections in the university-industry system could be improved, since some relationships are still unidirectional or present only weak ties. It can be problematic in developing countries' contexts where academia has a pivotal role in shaping the competitive capabilities of firms (Eun *et al*., 2006). Overarching institutional settings at the national level can either foster or hamper the engagement of universities in collaborative networks for frugal innovations. Ultimately, these initiatives are expected to drive societal and environmental impacts that can spillover nationally and internationally. Based on these arguments, we propose:

> Proposition 3: the effectiveness of entrepreneurial universities' strategies for managing technology transfer in frugal innovations is directly influenced by the ***existence/absence of adequate policies that promote social engagement in industrial activities, scientific research, and higher education***.

6. IMPLICATIONS AND CONCLUDING REMARKS

This paper analysed the strategic knowledge transfer practices implemented by entrepreneurial universities for fostering frugal innovations in emerging economies. Building on a case study of the University of Campinas, we propose a conceptual framework and a set of theoretical propositions that contribute to the ongoing academic discussions regarding (a) the strategic knowledge transfer practices implemented by entrepreneurial universities in emerging economies (Guerrero *et al*., 2019a, 2019b); and (b) the participation of entrepreneurial universities in the generation of frugal innovations to meet societal challenges (Annala *et al*., 2018; Chataway *et al*., 2014; Zeschky *et al*., 2011). The study provides relevant implications for the different stakeholders involved in developing university-business linkages for frugal innovations in emerging economies.

First, universities should strengthen internal ties between members of the academic community for the joint generation and dissemination of useful knowledge for frugal innovations. Reducing bureaucratic barriers for interactions with external agents, as well as setting up incentive schemes that reward involvement with frugal innovation, are critical for success. Frugal innovation, social innovation, and sustainability are emerging activities that have still not gained full legitimacy within the traditional organizational structures of universities. Existing incentives tend to prioritize other more traditional activities of universities' third missions, such as patent licensing, high-tech spin-offs, and income-generating consulting activities. Thus, a cultural shift is necessary to foster the kind of institutional change that re-aligns academic incentives towards frugal and social innovations, integrating them into specific policies and strategies throughout the academic system (Lozano *et al*., 2015).

Second, entrepreneurs and different types of incumbent firms need to intensify their connections with the academic environment to foster frugal innovation and sustainable development. It also requires building a more "purpose-driven" innovation ecosystem (Dahlmann *et al*., 2020), where entrepreneurs and incumbents integrate social, frugal and environmental objectives into their organizational purpose

rather than focussing only on financial objectives, and where they engage in new modes of collaboration with universities to achieve those objectives.

Third, policymakers in the field of innovation and higher education policies should also support a shift in the third mission of universities towards social, environmental, and frugal innovation. In particular, rather than seeking to import best-practice third mission instruments adopted in developed countries, policymakers in emerging countries should embrace a more context-specific approach to university-industry knowledge transfer that prioritizes frugal innovation and sustainable development (Benneworth *et al*., 2016; Guimón, 2017). For this purpose, each country needs to carefully select the most appropriate mix of policy instruments among those available, after carefully considering the local context and subject to a budget constraint (Guimón and Paunov, 2019). Also, the results of our study suggest that adopting an inclusive policy approach is of paramount importance, providing incentives that promote the participation of the different stakeholders involved in the entrepreneurial and innovation ecosystem, including disadvantaged communities and students. To achieve this, however, the engagement of civil society organizations such as associations, NGOs, and community leaders is also critical for the success of knowledge transfer initiatives oriented towards frugal innovation.

Finally, it is important to stress again that focussing only on university-level initiatives is likely to be inefficient in the absence of complementary actions involving innovation ecosystems and the broader institutional settings that shape agents' behaviour towards the co-creation of frugal innovations. Accordingly, the combination of efforts among policymakers, university managers, firms, and civil society are pivotal for such initiatives to take-off.

We acknowledge that our study has several limitations. Similar to previous studies in emerging economies (Guerrero *et al*., 2018), the critical challenge has been accessing longitudinal information. The analysis of strategic management practices for frugal innovation requires an evolutionary perspective. In this study, we tried to address the influence of the "variable time" using secondary sources of information (official documents and reports) in the Unicamp case. However, the collection of longitudinal information like subjective metrics based on the retrospective opinion of the respondents as well as objective metrics captured from multiple universities about the phenomenon should be considered in a future research agenda. The second limitation is related to the theoretical complexity of this phenomenon. A natural extension of this study should measure the social impact/effectiveness of university/regional capabilities for frugal innovation. Finally, policies and assessments often mirror trends observed in the developed world. It is unfortunate, as universities' connections with industries in laggard nations could provide more meaningful outcomes if better connected with the local environment. Further analyses in different contexts through qualitative and quantitative studies could explore the effective contributions of university-business linkages for frugal innovation, sustainable development and social inclusion.

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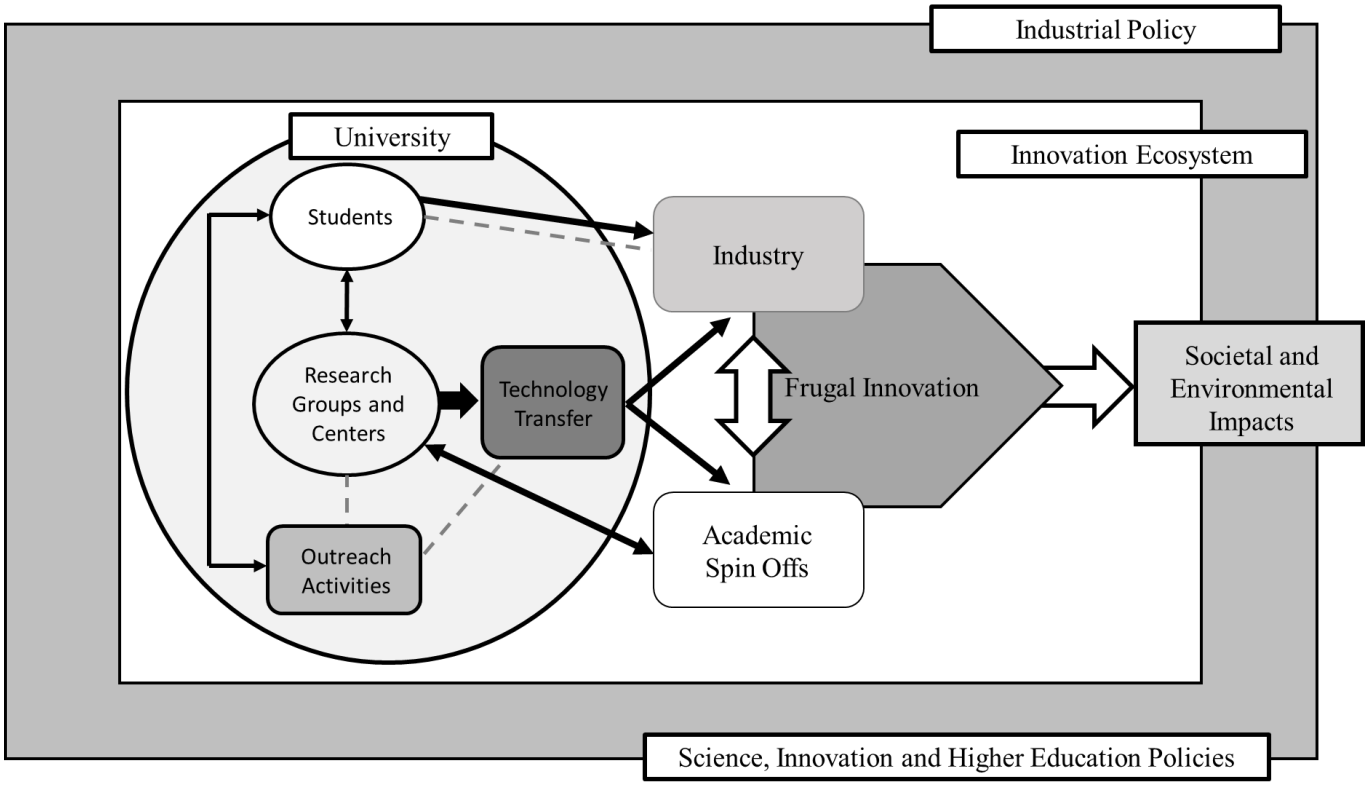
Figure 1. Proposed model



Notes: Unidirectional and bidirectional arrows identify the flow of relationships. Dashed lines represent weak ties. For example, students are connected to the industry through the supply of human resources and (weak) ties between student organisations and firms.

Source: Authors

Appendix 1. Description of Interviewees

ID	Organisation	Perceptions of frugal innovation	General Examples provided by UIC and frugal innovation	Knowledge Management in a context of University-Industry interactions for Frugal Innovation	Knowledge and frugal innovation transfer: the UIC perspective
1	Institutional Representative #1	The university established a strategic focus on social matters, including initiatives oriented towards the Sustainable Development Goals. However, concepts related to frugal innovation have not been fully incorporated, and projects associated with these impacts have not yet been mapped	The IP portfolio does not map potential frugal innovations. Cases mentioned involving mainly spin-offs from the university in health-related areas	Difficulty in establishing a culture oriented towards frugal innovations in an environment with incentive systems fundamentally oriented to scientific advances and publications. A key challenge, in this case, involves respecting researchers' autonomy. One way of dealing with this scenario is the establishment of indicators and their inclusion in evaluation systems	Companies' interactions with the university have evolved in terms of interest in social sustainability
2	Institutional Representative #2	The university has evolved in terms of establishing outreach activities that have a focus on developing adequate solutions together with society - instead of having a unidirectional transfer	Projects related to solar energy, affordable bras for women that went through a mastectomy. Also, impacts in terms of organizational innovations for vulnerable communities to become sustainable	As initiatives are highly decentralised, it becomes hard to establish a clear focus for frugal innovations throughout institutes and departments. Even though the university proposes a strategic focus, evaluation systems are not adequately designed to direct researchers' behaviour towards common goals	Engagement happens mainly with social enterprises. The main challenge, in this case, is to involve more faculty members in the process
3	Institutional Representative #3	Focus on social technologies and support to social enterprises. Impacts are mainly related to social inclusion, and it is not frugal innovation per se	Generation of organizational innovations in social enterprises, as well as projects of cleaner production systems	Main challenge reported was associated with technological development in incubated social enterprises—difficulty in establishing a functional relationship between these enterprises and the university's research infrastructure	Focus on social enterprises. Broader market impacts are less the focus than improving the quality of life in supported firms
4	Student Organization #1	Projects directed toward organizational innovations that empower vulnerable communities and/or social groups	Collaboration with the municipality to offer management consultancy for public institutions and social groups	Internal managerial difficulties because of high turnover rates of student members. Also, lack of engagement of faculty	Marginal participation of firms in collaborative projects
5	Student Organization #2	Joint developments with the community that allow wealth generation for vulnerable groups	Organisational innovation for workers and social entrepreneurs in the municipality	Lack of engagement of faculty and scarce institutional support	Support from local and multinational companies
6	Student Organization #3	The training targeted at developing leadership skills for social entrepreneurs	As the organisation was in its initial stage of operation, no concrete examples were provided	Lack of engagement of faculty	No relationships with firms yet

7	Research Center #1	Development of new technologies that reduce overall costs for brain treatments. Not necessarily frugal, but more cost-competitive than existing technologies	Affordable health technologies in neurosciences	Inova offers an institutional structure that facilitates connections with industry. However, the demand for technology is still scarce in Brazil	Lack of demand for joint projects with industry. The research center generated some successful spin-offs
8	Research Center #2	Innovations based on natural resources and biomaterials that have substantial impacts on cost reduction	Biomedical applications based on Açaí and sugarcane	The infrastructure for knowledge transfer has improved substantially. Also, the new regulatory framework for UIC in Brazil allows an easier connection with industry	Difficulty in establishing ties due to regulations for health industries. The research center has started to generate spin-offs recently
9	Research Group #1	Frugal innovation based on simple and effective engineering projects. Focus improvement of existing products aiming at cost reduction	Motorised wheelchair technology at affordable prices	Problems of internal management at the university, mainly related to communication issues and lack of a proper coordination system that promotes frugal innovations	Connections between universities and companies need to be improved. Bureaucratic barriers hamper a closer approximation
10	Research Group #2	Generation of environmentally and socially sustainable energy supply	Development of several strategies to reduce energy consumption at the campus	Full support from the university to develop joint projects with an industrial partner	Strong ties with industrial partners and the current generation of spin-offs. Technologies are being transferred continuously to firms
11	Spin-off #1	Address health issues that are currently tackled only by expensive technologies, leaving most of the population without support	Affordable health technologies for breast cancer detection	Unicamp's structure promotes a culture of entrepreneurship in its researchers, facilitating the translation of scientific results into marketable products	Relationships with faculty members from Unicamp are mostly informal. Connections happen in a decentralized way
12	Spin-off #2	Products that can reach out to medical patients in vulnerable conditions, offering cost-competitive technologies	Affordable health technologies for physiotherapy treatment based	Unicamp has a technical and managerial infrastructure that facilitates connections with its spin-offs	Strong collaboration with a research center at Unicamp. Shared use of laboratories
13	Spin-off #3	Supply of locally generated technologies to reduce the need for costly imports	Affordable organic tissue reconstruction	Norms for knowledge exchange seem to be suitable for large corporations, making it difficult for start-ups to navigate through legal requirements	Connections with the university still happen mostly informally due to complicated bureaucratic procedures to establish a formal collaboration
14	Large company (MNE)	Focus on energetic efficiency and its impacts on consumers	Social and environmental sustainability projects	Unicamp offers a robust scientific base that is complementary to the technical side of what the company does. An approximation is slow, and it begins mostly in an informal way, then it evolves to formal contracts	Strong connections with Unicamp. A constant flow of students and researchers. Long-term joint S&T projects. Prospective shared laboratories with the university